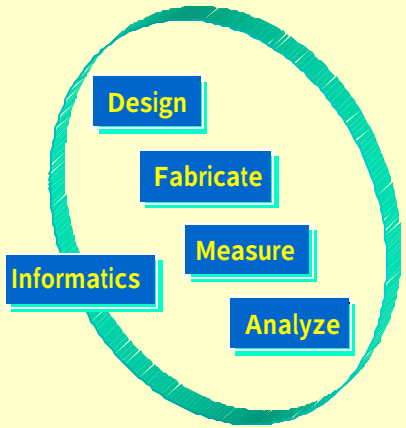
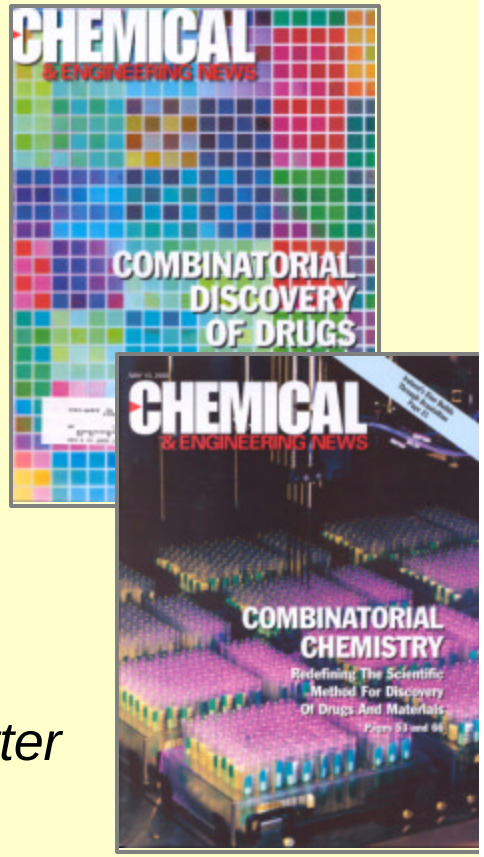
Combinatorial and High-Throughput Techniques Revolutionized the Pharmaceutical and Genomics Industries…



- Parallel Experiments
- Automated Specimen Array Fabrication
- Automated Analysis
- Iterative Approach

Faster, Cheaper, Better Product Discovery



…Now, materials scientists are applying combi approaches to accelerate materials research

A New Paradigm for Experimental Mat. Sci…

Vision:

Establish NIST as a global leader in Combinatorial Materials Science

Strategy:

- Establish a world class center (NCMC) for combinatorial and high-throughput material science for developing methods and measurements for the materials industry

- Co-ordinate effort within NIST on combi methods and share resources

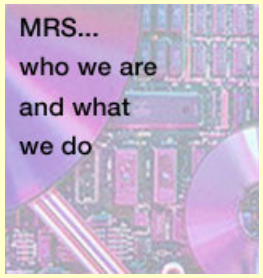
- Demonstrate scientific validity of the combinatorial approach in each step of the combi cycle for well defined classes of problems in materials science

Leadership Role

Symposium Organization

- **Materials Research Society, Fall 2001 (+Boston, Fall 2003)**
  (E. Amis, Organizer, E. J. Amis & A. Karim, Symp. Chairs)
- **Gordon Conference, 2002**
  Combinatorial & High Throughput Materials Science
  Jun 30-Jul 5, Kimball Union Academy (E. J. Amis, *Organizer)
- **New Technology Forum, ANTEC 2002, SPE**
  May 5-9, San Francisco, CA (A. Karim, Organizer)
- **ACS, 2004**
  Spring, Anaheim, CA (C. Davis, A. Karim, * Organizers)
- **Knowledge Foundation, Combi 2002 (+San Jose, Feb 19-21, 2003)**
  Jan 23-25, San Diego (E. J. Amis, A. Karim, * Organizers)

Gordon Research Conferences



Invited Publications

- **MRS Bulletin** "**Combinatorial and High-throughput Methods for Materials Science**", April 2002 focus issue.
- **Book Chapter** "**Experimental Design for Combinatorial and High-Throughput Materials Development**", Edt. James W. Cawse, GE Plastics, John Wiley, In Press.
- **Review Article** "**Combinatorial Methods for Materials Research and Development**", Kirk-Othmer (In WERB).
- **Review Article** "**Combinatorial Methods in Polymer Science**" for the Encyclopedia of Polymer Science and Technology, John Wiley, In Press.
- **ACS Book Chapter** "**Combinatorial Approaches to Materials Development**" in Combinatorial Polymer Science: Synthesis and Characterization", Dec. 2001.
- **Book Editor** "**Polymer Interfaces and Thin Films**", MRS Proceedings Fall 2001, In Press.
- **Invited Article** " **Combinatorial Mapping of Surface Energy Effects on Diblock Copolymer Thin Film Ordering**", Macromolecular Rapid Communications, In progress.
- **Book Chapter** "**High-throughput Image Screening for Knowledge Discovery**", High Throughput Analysis: A Tool for Combinatorial Materials Science, In progress.

~ 30 Publications on Combi research to date; (NISTIR 6730), (CD-NISTIR 6804)

Combi-Laboratory Developments

Laboratory Space

Renovation of Six-Lab module

User modules, Synthesis, Informatics

Double Lab module

Combi adhesion, Mechanical properties

Methods Developed for Library Fabrication

Heated Gradient Flow Coating

Dual-Vial+Syringe Composition Gradient

Continuous Pump Composition Gradient

Iso-Parametric, Autofocus Microscopy

Inverted MCAT, variations

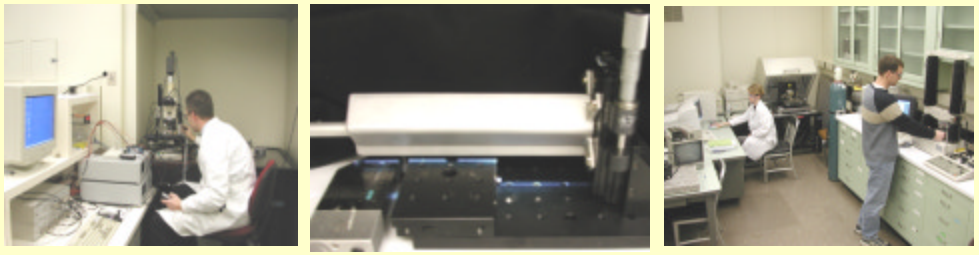
Copper-Grid Crazing, Fracture

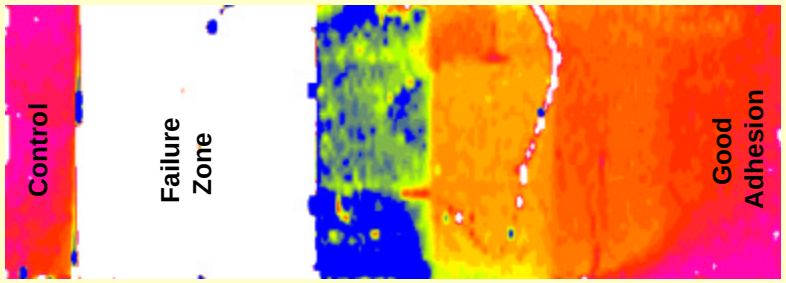
Youngs Modulus

Gradient Peel Test

UV-Surface Energy Gradient (SEG)

IR Composition Mapping





180º TAPE PEEL TEST – Effect of Gradient UV Exposure
C=O / C-O-CH_3 FTIR Map of PMMA / Aluminum Coated Si

Custom Analysis Programs

- Lab view instrument control
- NIH Image analysis
- IDL software
- Matlab (ITL, Beichl)
- Igor

NCMC-2, October 7-8, 2002
Adhesion and Mechanical Properties
Bldg. 101 / Lecture Rm. B

Monday, October 7th, 2002

8:00 am Registration, Bldg. 101 / Lecture Rm. B
Coffee & Doughnuts

8:30 am Welcome and Introductions
Alamgir Karim

8:40 am Recent Advances in Adhesion Studies using Contact Mechanics
Manoj Chaudhury, *Professor, Department of Chemical Engineering, Director of the Polymer Interface Center*
Lehigh University

9:40 am *Coffee Break*

10:00 am Materials Issues and Adhesion Impact on Reliability of Cu/low k interconnects
Paul Ho, *Professor, Engineering*
Department of Mechanical Engineering
University of Texas

11:00 am Presentation and Tour of NIST Service Life Prediction Facilities (Bldg. 225)
Christopher White

12:15 pm *Lunch* (NIST cafeteria, Bldg. 101)

1:35 pm Multilens Contact Adhesion Test Method (MCAT)
Alfred Crosby

2:20 pm Combinatorial Adhesion Test Examples & Discussion
Christopher Stafford

2:40 pm *Coffee Break*

3:00 pm Combinatorial Edge-delamination Test for Thin Film Adhesion
Martin Chiang

3:20 pm Combinatorial Peel Test Method for Adhesion
Rui Song

3:50 pm Poster Session-General Combi Methods (Hallway outside Lecture Rm. B)
Michael Fasolka, Organizer

5:30 pm Social Dinner, Buca di Beppo
(122 Kentlands Blvd. Gaithersburg)

Tuesday, October 8th, 2002

7:45 am *Coffee & Doughnuts*

8:00 am Overview on Polymer Craze and Fracture using the Copper Grid Technique
Chang Ryu, *Chemistry Department & NYS Center for Polymer Synthesis*
Rensselaer Polytechnic Institute

9:00 am Combinatorial Measurements of Polymer Craze Growth using the Copper Grid Test Method
Kathryn Beers

9:40 am *Coffee Break*

10:00 am A High-Throughput Test Method for Mechanical Properties of Thin Films
Christopher Harrison

10:45 am Combinatorial Laboratory Demonstrations
Christopher Stafford- Organizer

12:00 pm *Lunch*
(NIST cafeteria, Bldg. 101)

1:30 pm NCMC Practical Knowledge Toolkit
Michael Fasolka

1:50 pm Panel Discussion: Future Members Needs
Eric Amis; Polymers Division Chief
Kapeeleshwar Krishana; Rhodia, Inc.
Coffee Served

3:30 pm Laboratory Demonstrations-2
(Optional)

Poster Session Program
NCMC-2
October 7, 2002

1. **4Wave Inc.**
   Todd Hylton, Augustine Middleman, David Day
   4Wave Inc.

2. **The Use Of Micromachined Arrays For Efficient Materials Processing/Performance Studies.**
   S. Semancik, C. J. Taylor and R. E. Cavicchi,
   Chemical Science and Technology Laboratory, NIST

3. **Combinatorial Methods for Group III – Nitride Nano-Optoelectronics**
   A.V. Davydov[1], L.A. Bendersky[1], D. Josell[1], A.J. Shapiro[1], W.J. Boettinger[1], P.K. Schenck[2], J.E. Blendell[2], K.S. Chang[3] and I. Takeuchi[3]
   [1]Metallurgy Division / [2]Ceramic Division, NIST
   [3]Dept. of Materials and Nuclear Engineering, University of Maryland, College Park, MD

4. **Pulsed Laser Deposition as a Combinatorial Tool for Inorganic Thin Films**
   Peter K. Schenck and Debra L. Kaiser
   Ceramics Division, NIST

5. **Spectroscopic Reflectometry as a High Throughput Tool for the Analysis of Combinatorial Thin Films**
   Peter K. Schenck, Debra L. Kaiser and Albert Davydov
   Materials Science and Engineering Lab, NIST

6. **Imaging Chemical and Molecular Nano Properties : Combinatorial NEXAFS, Pictures & Movies**
   Daniel A. Fischer[1] and Jan Genzer[2]
   [1]Materials Science and Engineering Laboratory, Ceramics Division, NIST
   [2]Dept. of Chemical Engineering, North Carolina State University

7. **Adapting Sequential Material Property Techniques for Higher Throughput Experimentation**
   Steve Robbins and Michael Rusak
   Air Products and Chemicals, Inc.

8. **Combinatorial Approach To Functional Metal-Oxide Thin Films**
   Kao-Shuo Chang, Maria Aronova, Olugbenga Famodu, J. Hattrick-Simpers, I. Takeuchi
   Dept. of Materials and Nuclear Engineering, University of Maryland, College Park, MD

9. **Combinatorial Approach To Magnetic Metallic Alloys**
   Olugbenga Famodu, Maria Aronova, Kao-Shuo Chang, C. Ziegler, I. Takeuchi
   Dept. of Materials and Nuclear Engineering, University of Maryland, College Park, MD

10. **High-Throughput Characterization of Mechanical Properties in Combinatorial Polymer Libraries**
    Joe-Lahaia Sormana, J. Carson Merideth
    Dept. of Chemical Engineering, Georgia Institute of Technology, Atlanta, GA.

11. **High Throughput Measurements of Epoxy Curing by Confocal and FTIR Microscopy**
    D. Raghavan[1], N. Eidelman[2], A. Karim[3], and E. Amis[3]
    [1]Polymer Group, Department of Chemistry, Howard University, Washington DC;
    [2]ADAHF, PRC, NIST, [3]Polymers Division, NIST.

12. **Combinatorial Mapping of Polymer Film Wettability On Gradient Energy Surfaces**
    Karen M. Ashley[1], Amit Sehgal[2], D. Raghavan[1], and Alamgir Karim[2]
    [1] Polymer Division, Department of Chemistry, Howard University, [2] Polymers Division, NIST.

13. **Rapid-Prototyping and Fabrication of Solvent Resistant Fluidic Devices**
    Joao Cabral, Chris Harrison, Kathryn L. Beers, Alamgir Karim, Eric Amis
    Polymers Division, NIST

14. **Mapping Isotactic Polystyrene Crystallization with High Throughput Methods**
    Kathryn L. Beers, Alfred J. Crosby, Jack Douglas, Alamgir Karim and Eric J. Amis
    Polymers Division, NIST

15. **Block Copolymer Thickness-Gradient Surface Patterns on Topographically Structured Substrates**
    M.J. Fasolka[1], T.A. Germer[2], A. Karim[1], E. Amis[1]
    [1]NIST Combinatorial Methods Center, NIST.
    [2]Physics Laboratory, NIST

NCMC Future Directions

1) Informatics

- e-data management, e-notebook, “intelligent” instrument control…)
- More efficient technology transfer (Web…
- Potential new area: MEMS



2) Combinatorial Adhesion and (Micro) Mechanical Properties

- Pressure Sensitive Adhesives (PSA)
- Toughness, Viscoelasticity, Rough Surfaces
- New Area: Weak Adhesion (e.g. Bio-Adhesion)




3) Polymer Formulations

- Emulsions with polymeric surfactants / polymers
- Handling high dimensional component & parameter space
- New Area: Modular Millifluidics